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## Using Landsat Imagery to Monitor Post-Fire Vegetation Recovery in the Sandhills of Nebraska: A Multitemporal Approach.

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# Using Landsat Imagery to Monitor Post-Fire Vegetation Recovery in the Sandhills of Nebraska: A Multitemporal Approach.

By

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AN UNDERGRADUATE THESIS

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Under the Supervision of Dr. Donald Rundquist

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# Using Landsat Imagery to Monitor Post-Fire Vegetation Recovery in the Sandhills of Nebraska: A Multitemporal Approach.

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University of Nebraska, 2012

Advisor: Dr. Donald Rundquist

## **Abstract**

The objective of this study was to look at a wildfire in the Nebraska Sandhills as a case study for multi-temporal monitoring of burned areas using Landsat-7 satellite images. Eight Landsat-7 scenes were selected and a shapefile of the perimeter of a September 2000 wildfire in the Fort Niobrara National Wildlife Refuge. A true color composite, color infrared composite, and a single-band NDVI output was used for visual analysis. A subset of burned and unburned sections was taken from the NDVI images; the values were graphed and compared. The visual analysis of the true color and color infrared images show the presence and absence of vegetation. The NDVI can be used to quantify the amount, and relative health of the vegetation present. Landsat-7 imagery, especially when converted to NDVI is a useful tool for land managers looking a cheap, and efficient way to monitor landscape level changes.

## **Acknowledgements**

I would like to thank Dr. Don Rundquist for taking the time to help me with the study in the capacity of thesis advisor, Kathryn Pfaffle for serving as my thesis reader. The Fort Niobrara National Wildlife Refuge for providing the shapefile of the fire perimeter. And to Dr. Dave Gosselin and Sara Cooper for their countless hours of support in their roles as the Environmental Studies Program Director, and Advisor.

## **Introduction**

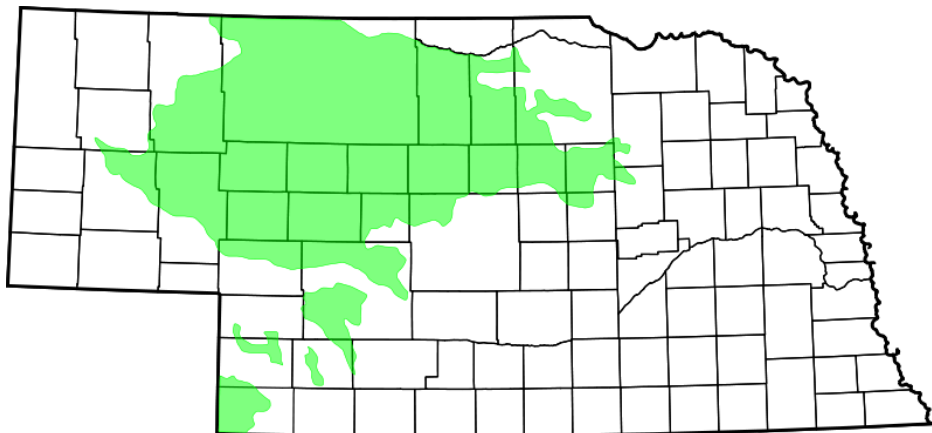
Fire plays an important role in ecosystem health, and is frequently used by land managers to maintain or restore natural ecosystems. (Covington, William, Wallace, 2003.) Fire has played a larger role in shaping and maintaining grasslands than any other type of ecosystem. (Chin, Gilbert, and HJS, 2005.) Monitoring burned areas post-fire is an important part of land management plan. (Dale, Lisa, 2006.) Remotely sensed imagery is a tool used for rapid and efficient for landscape scale monitoring activities. The ability to track the changes of a remote location over time without having to make repeated visits to the area, which ends up being very costly, makes remote sensing a critical tool for landscape scale monitoring.

The Landsat Satellite System is a convenient remote sensing platform for monitoring post-fire areas. Landsat is a joint program between The National Aeronautics and Space Administration (NASA) and The United States Geological Survey (USGS). Landsat-7 is the latest orbiter in the satellite series. It was launched in April of 1999 and has a return period of 16 days, meaning its orbits 16 days long. Each image covers an area of 183km by 170km and has a spatial resolution of 30 meters; except for the panchromatic channel and the thermal-infrared band, which have 15 meter and 60 meter resolution, respectively. Table 1 contains the relevant technical information.

<b>Landsat 7 Bands</b>	<b>Wavelength (micrometers)</b>	<b>Resolution (meters)</b>
Band 1	.45-.52	30m
Band 2	.52-.60	30m
Band 3	.63-.69	30m
Band 4	.77-.90	30m
Band 5	1.55-1.75	30m
Band 6	10.40-12.40	60m
Band 7	2.09-2.35	30m
Band 8	.52-.90	15m

**Table 1:** Landsat 7 ETM+ band designations. Bands 3 is the red band, and band 4 is the near infrared band.

The Nebraska Sandhills Region in Nebraska is the largest stable dune system in the western hemisphere (figure 1) (Department of Interior, n.d.). The Sandhills Region is largely covered in grasses; mainly Sand Reedgrass, Sand Bluestem, and Little Bluestem and dotted with seasonal wetlands and valley ponds (Kody, n.d.). The region experiences occasional, low intensity burns, which are either prescribed or naturally ignited. ("Worlds Biomes.") Fires occur due to the hot and dry climate of the Sandhills. Although there are wetlands and ponds in the area due to the extensive water resources in the Ogallala Aquifer, the climate tends to be dry and hot during the summer and fall months, creating fire hazards (figure 2).



**Figure 1: Nebraska Sandhills**

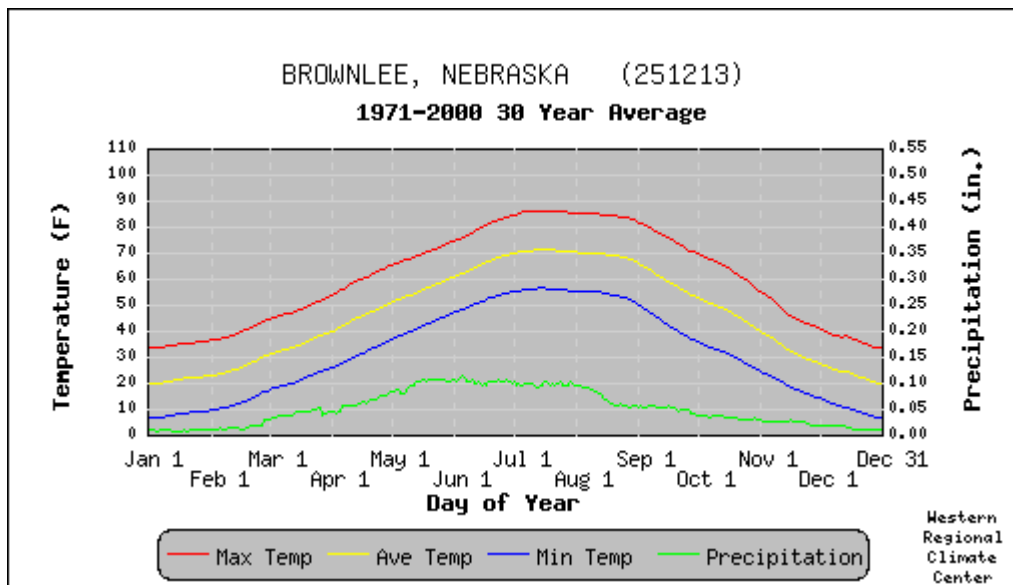


Figure 2: Sandhills Weather Data (High Plains Regional Climate Center, 2012)

During September 2000, a series of wildland fires burned an area approximately 91.5 km<sup>2</sup> in the Fort Robinson National Wildlife Refuge. This fire was selected as a case study for the multi-temporal monitoring of the burned area using Landsat images and the Normalized Difference Vegetation Index Bands (NDVI).

After a fire a series of changes in the spectral reflectance occur due to the fire clearing the vegetation that is green and photosynthetically active. This drop in chlorophyll levels results in an increase in the visible region (blue through red, corresponding to Landsat bands 1-4) of the electromagnetic spectrum, and a decrease in the shortwave-infrared region corresponding to Landsat band 4 (Escuin, Navarro, and Fernandez 2008).

There are several spectral indices, which allow measurement of change in individual spectral bands. One of the most well known is NDVI, which is calculated using the following equation.

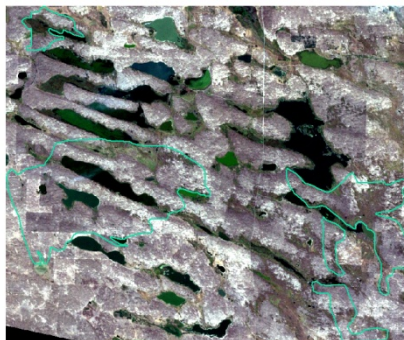
$$NDVI = (Near\ IR - Red) / (Near\ IR + Red)$$

Chlorophyll pigment in plant chloroplasts absorbs a considerable amount of the incoming red light while reflecting the near infrared energy (green?). The NDVI algorithm produces values between -1 to 1. Values greater than zero indicate the amount and condition of green vegetation, while negative values (less than zero) indicate non-vegetated features (USGS, 2010).

Using NDVI in a multi-temporal dimension gives a good indication of post-fire vegetation recovery. A visual analysis of a series of images and corresponding NDVI data should give a land manager an indication of the vegetation health following fire occurrence.

## **Methods**

Eight Landsat scenes were downloaded as level-1 products from [glovis.usgs.gov](http://glovis.usgs.gov) (a web portal operated by the USGS). The scenes selected had 30% or less cloud cover, so the cloud cover could not obscure any part of the study area. These images were next uploaded to ENVI, an image processing software package, and a preprocessing Landsat calibration operation was performed on each image, converting the digital numbers to top atmosphere reflectance. Each image was subsequently manipulated into a true color composite, and a color infrared composite (CIR), using the following equation in Band Math in ENVI produced the NDVI image.



$$(float(b4)-float(b3))/(float(b4)+float(b3))$$

Bands 4 and 3 were selected as the variables (b4) and (b3).

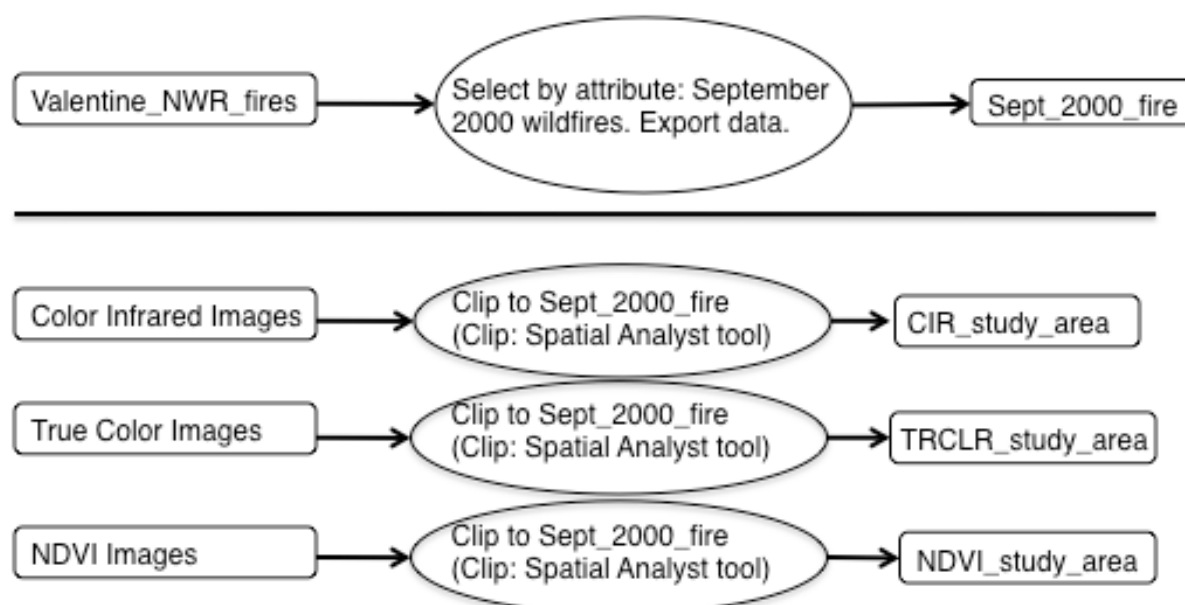
This created a single band NDVI output. Next, a NDVI

**Figure 3: Study Area**



subset was taken, using screen digitizing in ENVI; 4 areas were chosen: two burned, and two non-burned with an average area of 9 km<sup>2</sup>. The Average NDVI was taken for each set, burned and unburned. The averages were graphed (Figure 5).

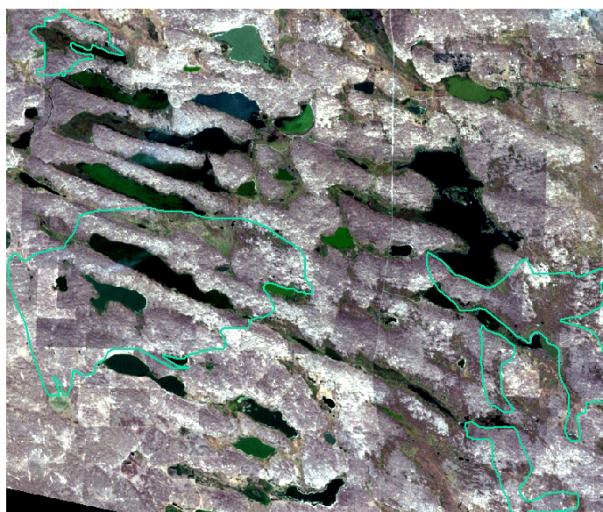
The images were subsequently exported as an IMAGINE file format, and then imported into ArcGIS. A shapefile was obtained from Fort Niobrara National Wildlife Refuge; the September 2000 wildfire was selected in the attribute table and exported to a new layer. This new layer was overlain onto each image. The Landsat images were clipped to the fire layer, delineating the study area to approximately 25.5 km by 21.2 km (Figure 3)



**Figure 4: Data Layers Flowchart**

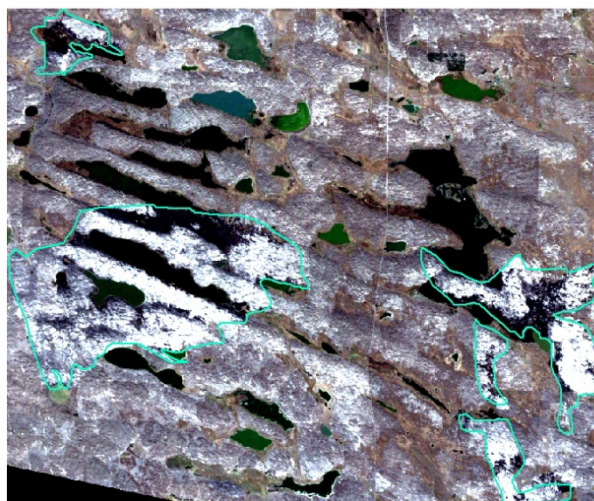
## Results

September 2000  
Image 1



Fire Perimeter  
fire perimeter

October 2000  
Image 2



Fire Perimeter  
fire perimeter

September 2001  
Image 3

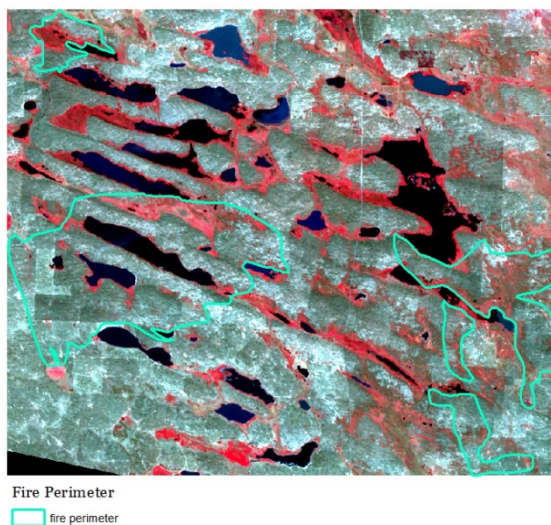


Fire Perimeter  
fire perimeter



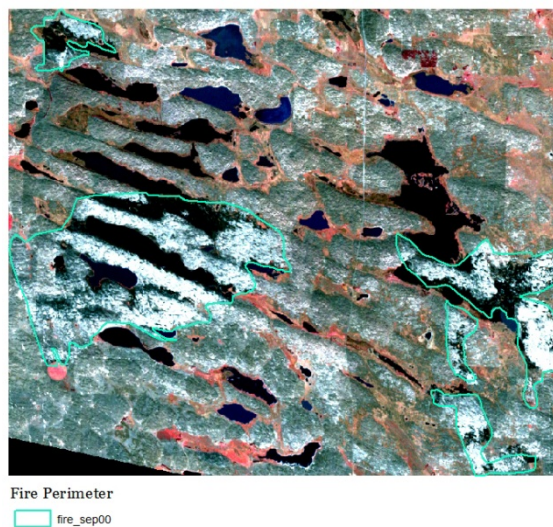
September 2000

**Image 4**



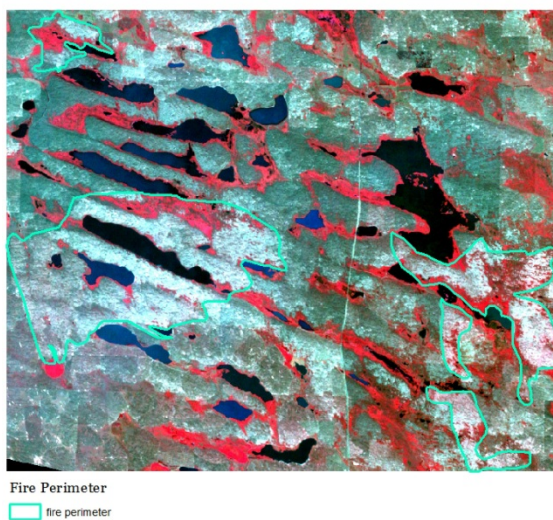
October 2000

**Image 5**

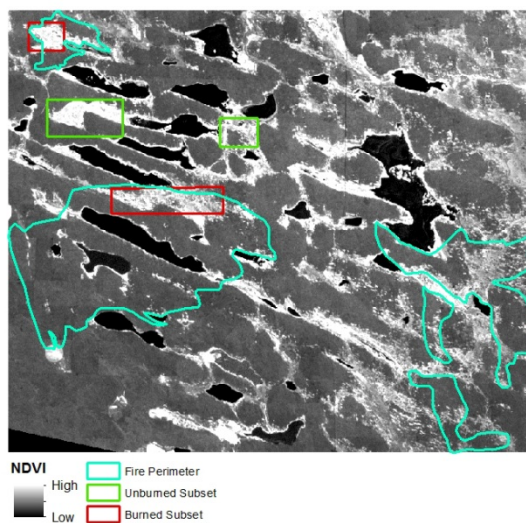


September 2001

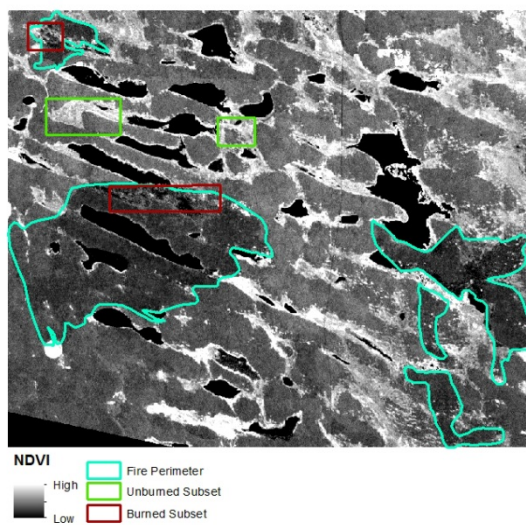
**Image 6**



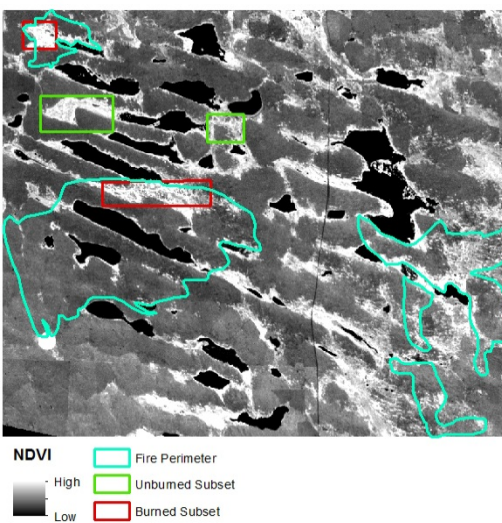
September 2000  
Image 7



October 2000  
Image 8



September 2001  
Image 9



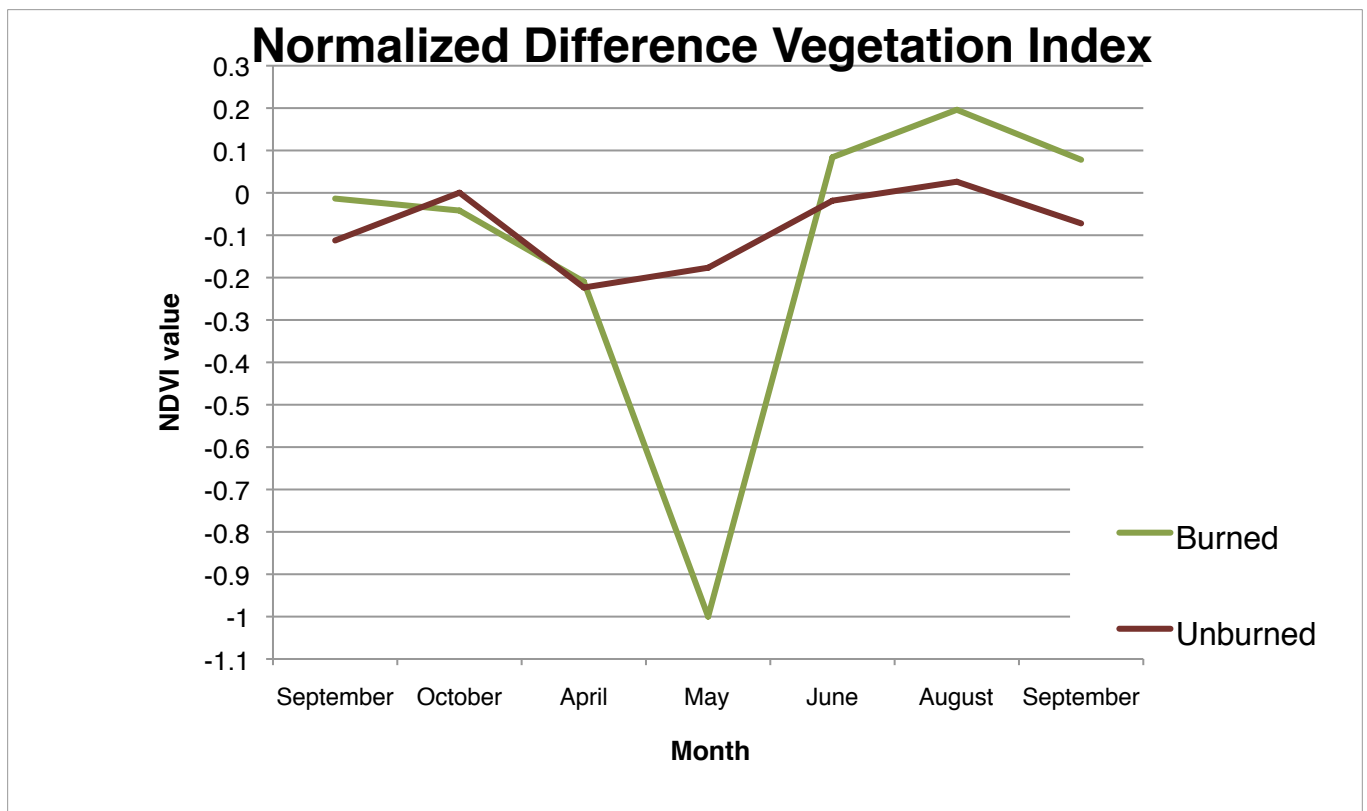


figure 5: Average NDVI values over time, burned and unburned subsets.

The first three images are shown for reference purposes only. The next three images (images 4-6) are color infrared images; a change in the reflectance of infrared energy can be detected in the areas that experienced the burn. The last 3 images (Images 7-9) are the single band NDVI images that were used to quantify the average NDVI values for the subset areas.

Figure 5 shows the change in NDVI over the course of the study period. The focus is on the growing season the year after the fire occurred, starting April 2001, due to the winter months providing no useful information, snow cover and senescence of photosynthetically active plants drive the NDVI to low values for both areas.

## **Discussion**

Fire plays an important role in ecosystem health; it is imperative to study the effects fire has on the landscape. This study used remote sensed imagery to perform a

study at the landscape scale in a rapid and efficient manner. The true color images (1-3) are a useful reference tool. The perimeter of the burn is clearly visible in October 2000 image (image 2) and the perimeter can be roughly estimated even a year later (image 3).

The CIR images (4-6) are useful for looking for the presence or absence of vegetation. The October 2000 image (image 4) shows a complete absence of vegetation within the fire perimeter. While a year later in September 2001 (image 6) there is a flush of vegetation within the perimeter, noted by the bright red areas. This type of image manipulation, used over a series of images, can give the land manager a rough estimate of landscape health.

The NDVI images (7-9) are the most useful in order to quantify the difference in photosynthetically active vegetation. Not only can a distinct presence and absence within the perimeter be determined by looking at the images, but it is also easy to generate charts using the information provided by the image. Figure 5 shows the difference in the average NDVI values in the two subsets; burned and unburned. The graph only shows September and October of 2000, right before and immediately after the fire, then it skips ahead to the next growing season. Interestingly, there isn't a huge break in the two categories values following the fire in October; this is probably due to the vegetation that is present in the unburned subset that was dry and beginning to go dormant for the winter.

Once the growing season starts in April of 2001, the average NDVI values start to increase slightly, showing signs of growth. While the burned area has average NDVI values that are still falling, it isn't until May that the burned area starts seeing recovery of photosynthetically active vegetation. Once the NDVI values start increasing, the burned

area quickly matches the unburned area and then surpasses it. Before starting to fall again in September for the same reasons why the unburned areas see values starting to fall in autumn.

### **Conclusion**

This study was aimed towards showing that remote sensing is a useful management tool and that quantifiable data could be taken from the images using basic image enhancements and simple band math. The grassland fire was chosen for the quick recovery time, because drastic changes could be detected by the next growing season, i.e. a year after the event occurred. By showing that a land manager could manipulate images and be able to monitor landscape level changes. By using remote sensed imagery in a more prevalent manner, managers could save resources by not having to perform as many field studies to get an accurate account of the rate of change.

Future studies in this area should include using more study areas, with different types of landscapes and vegetation to accurately display the extent to which NDVI can be used. Another suggestion would be to use digitizing to enclose the entire perimeter of the fire instead of simply laying boxes within the perimeter Matching the size in the unburned areas is something that should be done for future studies.

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